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Industrial Research Institutes' Collaboration: a three-way solution to integrating new research skills

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Abstract

Innovation processes in emerging fields of technology frequently utilize scientific knowledge and technical skills from several research areas. Likewise, technological development frequently involves a diverse set of organizations including for example private firms, universities, corporate research labs and public or semi-public research and technology organizations (RTOs). These processes spur the need for both organizational and institutional change and adjustment, e.g. in order to facilitate research and development (R&D) and formation of innovation networks. The main question analyzed in the paper is how RTOs cope with integrating new skills in their competence base in the quest for exploring new emerging science fields and technology applications. The empirical setting consists of Swedish semi-public industrial research institutes active in the fields of pulp & paper technology and electronics, optics & communication technology respectively. The results of the study bring attention to three ways of integrating diverse skills and types of actors in R&D networks. These are: organization of collaborative research in formalized industry-specific R&D programs, purposeful organizational change also including redefinition of categories of core research competence and finally by targeting 'open' innovation processes characterized by incorporation of both end-users and skills of neighboring technology areas.

Keywords: Industrial research institutes; Innovation networks; Emerging technology; RTOs; Collaborative R&D; Interdisciplinary; Innovation policy, management and organization; Sweden

JEL: L20, L33, L52, L80, L84, O25, O31, O32, O38

1. Introduction

Innovation processes often involve actors from a variety of organizations, including private firms and corporations, universities, research labs, technology transfer offices and public or semi-public research and technology organizations (RTOs). Furthermore, the fusion of competences in exploring cross-disciplinary emerging fields of science and technology requires involvement of knowledge and skills from different types of organizations or dedication to interaction among different professions within one organization.

Collaborative forms of knowledge production and innovative activity enable actors to reduce risk, specialize, and take advantage of knowledge internal and external to the own organization. Previous studies of collaboration and innovation processes using patent data describe for example that collaborative efforts are more effective in terms of getting patents granted (Wilhelmsson 2007). However, at the same time collaboration can lead to conflicts of interest and expose opposing norms and strategies concerning, for example, the use of results, knowledge and innovations. Different ways of organizing collaborative efforts, (e.g. partnerships, alliances, networks, short-term or long-term projects, joint ventures, or even mergers) can be influenced by aspects such as strategic decisions regarding development of areas of core competences, path dependency (continuity and previous investments in machinery and technology), industry characteristics, etc. These choices in turn shape the collaborative efforts and outcomes. Common efforts also require regulative agreements, including formal contracts, rules and regulations (Powell et al. 1996; Teece 1986) and informal understandings, such as norms and practices shared between the collaborating parties (Scott 2001, 2003).

In this paper we analyze how collaborative and interdisciplinary research efforts are organized and funded at semi-public research institutes, a type of RTO. We also study the processes of organizational change facilitating new directions in research and development. By applying this focus we are interested in the following main question:

How do industrial research institutes cope with integrating new skills in their competence base in the quest for exploring new emerging technology applications?

The research question is investigated in the following paper through a case study of two Swedish industrial research institutes, STFI-Packforsk and Acreo.

We argue that it is relevant to study different ways to integrate new skills in organizations in order to get a better understanding of knowledge processes based on collaboration in research. This includes studying formal (regulatory) research agreements between RTOs, but also acknowledging norms and practices adopted and how the organization define core competences (i.e. recognition of categories describing these core competences). This translates in organizational studies, to the three categories of regulatory (laws and rules), normative (values and norms) and cognitive categories of institutions (Scott 2001).

By examining the practical arrangements of collaborative projects involving semi-public research institutes, this study also raises questions at the heart of public-private knowledge regimes. There has been a shift towards collaborative innovation processes in most industrialized countries (Mowery and Rosenberg 1989). Previous studies illustrate the critical role of public research organizations (committed to open norms of information disclosure) for cohesiveness of innovation networks in the area of biotechnology (Owen-Smith and Powell 2004, pp. 10-11). The case of industrial research institutes gives rise to an interesting case here since they involve both industrial partners with an entrepreneurial agenda to reap the benefits of their investments, and at the same time fulfill an education function and also incorporate PhD students with a clear aim of getting their papers published in scientific journals during their doctoral education. Research examining hybrid-order of scientific publication and patenting activity argue that there is a “fundamental change in the rules governing universities’ knowledge dissemination practices” (Owen-Smith 2003, p. 1099) that also can be recognized at research institutes. An increased importance of companies’ search for external scientific knowledge and technical skills, due to downsizing of their own research labs and processes of internationalization (Tijssen and Calero-Medina 2004) can furthermore result in an increased role of the industrial research institutes. There is also a surge of collaborative sector-based R&D programs and centers of excellence located at the industrial research institutes. These R&D programs and centers promote participation (and funding) from industry besides involvement of PhD students from academia (Vinnova 2005, 2007). This brings urgency to an increased understanding of the locus of collaborative innovation processes involving actors with inherently different norms, values and practices for knowledge production and dissemination. These existing inter-organizational ties between

firms, university and research institutes merit further analysis of the mechanisms of interaction, i.e. internal institutions facilitating (or hampering) interaction between different types of organizations.

There has been considerable experimenting regarding the scope of activities and organizational forms in the RTO sector in Europe during recent years, triggered among other factors by institutional reforms and changing sources of funding (Preissl 2006). Different organizational options and configurations have been investigated and tried among the institutes in order to adapt to the new and changing conditions. Similar development can also be observed among technology transfer offices (TTOs) which in some parts perform a similar function to that of RTOs, i.e. acting as an intermediary between industry and academia (European Investment Fund 2005, Tahvanainen and Hermans 2008). European TTOs are constantly changing and vary greatly with regard to organizational forms and activities (Conti et al. 2007).

Historically, research institutes in Sweden had the function of knowledge transfer from academia to industry as well as a service function for industry sectors (Weinberger 1997, p. 316). Today, there is a rich flora of different industrial research institutes, each shaped by its own unique circumstances. Roughly three types of institutes can be identified (Sörlin 2006). The first group consists of institutes dedicated towards particular scientific fields, for example surface chemistry or computer science. The second type includes institutes that focus on specific industry sectors with a strong presence and tradition in Sweden, like paper and pulp industry or manufacturing industry. Thirdly, there are institutes that specialize in providing particular functions directed towards all industrial sectors, for example technical evaluation and testing or consulting services in areas such as quality and continuous improvement.

The empirical case of science-based technology we examine here focuses on the first and second category of institutes, outlined above, and is used to provide a richer account of contemporary institutional underpinnings of collaborative innovation activities. The material used for the study includes R&D programs and other documentation from institutes in addition to interviews with institute representatives with experience of institutes' collaboration and with researchers within the field examined. Another part of this project, not accounted for in this paper, has a stronger historical focus examining the background to current industrial research institutes analyzing early Governmental Bills and historical

archives to get a thorough understanding of roles formulated for industrial research institutes in Sweden in different time periods, starting in the 1940s (Pettersson 2008).

This paper is composed of four parts. Following the introduction, key concepts and theory framework are outlined. Then, the third section of the paper includes a brief historical background to the Swedish research institutes followed by the results from the case studies. The final section of the paper consists of a concluding discussion on interdisciplinary technology as a collaborative endeavor.

2. Institutes' knowledge integration framed in institutional theory

The theoretical framework for this paper builds on organizational studies and institutional theory applied to studies of innovation networks in the context of collaborative R&D of industrial research institutes. The study acknowledges the importance of institutions external as well as internal to the organization, such as norms and regulations, in shaping the character of links between actors in innovation networks. In addition to drawing from experiences of organizational studies, the topic of industrial research institutes' collaboration motivates incorporating elements of science and technology studies and studies of geography of collaboration. Key concepts of absorptive capacity, exploration-exploitation, institutional elements and geographic proximity provide a framework for the empirical cases examining different ways to integrate new knowledge.

2.1 Absorptive capacity and technology strategy

Given the focus on integration of new (and often external) knowledge required for advancing new fields of technology development, the concept of absorptive capacity (Cohen and Levinthal 1989, 1990) serves as a good starting point for outlining previous studies and concepts relevant for this study. Absorptive capacity is defined as "ability to identify, assimilate, and exploit knowledge from the environment" also including "the ability to exploit knowledge of a more intermediate sort, such as basic research results that provide the basis for subsequent applied research and development" (Cohen and Levinthal 1989, p. 569-570). The implications of absorptive capacity are also discussed for decisions to participate in co-operative R&D ventures (Cohen and Levinthal 1990). In later studies the theory of absorptive

capacity has been developed further in different directions. It has been proposed that the level of absorptive capacity in a given organization is influenced both by organizational forms and combinative capabilities (Van den Bosch et al. 1999). The form of an organization can for example in some instances impede absorption of new knowledge but it also can "facilitate the scope and flexibility of knowledge absorption" (Van den Bosch et al. 1999, p. 567). Since firms often create new knowledge by reconfigurating the competencies they already control even the internal combinative capabilities are crucial (Kogut and Zander 1992). The concept of absorptive capacity has also been applied at the national level (Criscuolo and Narula 2008).

In our case discussing interdisciplinary technology, we also include in the concept the ability to apply knowledge from another discipline (by interaction with or incorporation of new skills into an organization). This 'interdisciplinary absorptive capacity' between organizations is facilitated by interaction between professions working across scientific disciplines (technicians etc). Earlier studies of cross-disciplinary research have pointed out that researchers that link between different disciplines by interacting with different science fields generally come from hybrid disciplines or are either "methodologists or technicians" (Rhoten 2003, p. 6). The interpretation is that having a strong theoretical focus can open up for cross-disciplinary applications of theoretical knowledge and that focus on measurement techniques also is a type of knowledge that can be applied across disciplines. This is also in line with technology studies' standpoint that engineers "use science as one cognitive tool among several in a pragmatic blend of theoretical expertise and experimental judgment" (Staudenmaier 2002, pp. 168-169).

However, at the organizational level, integration of new skills also comes with a cost. Hence, certain organizational processes focus less on exploration and more on exploitation of existing knowledge and capabilities (March 1991). For the organization to make use of the ability to apply this new knowledge, it also means introducing practices in the organization that favour exploration of possible areas of application and forms for interdisciplinary interaction. This also implies that organization studies with an interest in organizational change are inevitably faced with addressing the question of organizational inertia favouring existing core competences and associated practices. This is both described along the lines that organizations are largely unable of strategic adaptation due to structural inertia (Friedland and Altford 1991), or (at the level of the firm) as a failure "in matching the firm's systems of

coordination and control to the nature of available technological opportunities" (Pavitt 1998, p. 433). In contrast to this, the work on strategic niche management recognizes the strategy component and agency of actors in exploring and exploiting niches of new technology (Kemp et al. 1998).

Scholars of science and technology studies also examine conditions for research collaboration in science-based technology development (Katz and Martin 1997) applied in different fields of innovation (Meyer-Krahmer and Schmoch 1998). Likewise, they tackle the issues of examining costs and benefits of collaboration in stages close to commercialization (Hagedoorn et al. 2000). Three interrelated structural factors are put forward in explaining industry's attraction to external knowledge (Tijssen and Calero-Medina 2004). These include that : 1) companies have reduced their investments in long-term (and more basic) in-house research and instead enter cooperative interorganizational arrangements sub-contracting risky and long-term research to private labs or public sector research institutions; 2) processes of internationalization where firms seek out the most advanced knowledge and world-class researchers, and 3) the crucial role of intangible 'tacit' knowledge incorporated in experience (of technical personnel) without being written down. This is also described as a structural factor giving an increased importance of joint R&D labs.

Some of these R&D labs are hosted by the research institutes. For the current study examining ways institutes go about to integrate new knowledge it is particularly interesting to know more about R&D ventures that also require an understanding and interaction with other disciplines and professions. Professionalization processes based on a disciplinary science base can be contested (or at least not taken for granted) by integrating complementary competence relevant for development of interdisciplinary science-based technology. Furthermore, there are different types of interdisciplinary interaction (from recognition to more extensive interdisciplinary interaction) in early and later phases of collaboration that also, in the long term, can affect professionalization processes in new interdisciplinary fields of technology.

Processes of professionalization is also a taken into consideration in describing isomorphic processes (normative, mimetic and coercive) that make organizations more similar, without necessary making them more efficient (DiMaggio and Powell 1983). These processes are enforced by i) formal education and legitimation in a cognitive base produced by university

specialists, and ii) growth and elaboration of professional networks that span organizations and across which new models diffuse more rapidly.

2.2 Institutional agreements at institutes

The current study acknowledges the normative and regulative nature of institutional agreements as described in R&D programs and institute strategy statements. By using the term institutional agreement, we emphasize that that these research organizations and their labs are an arena for interaction between, not only different research performers, but also harbor a variety of contesting norms on functions of institutes. These include the entrepreneurial task exploring novel areas of applications for both existing and future technology, being service providers to established industry sectors and also educate students and produce PhD-theses based on scientific publications. Having said that, the research institutes studied here are actors on the knowledge production arena where integration of novel skills also implies creating cognitive categories that describe areas of competence. In organizational studies, the three categories of regulatory (laws and rules), normative (values and norms) and cognitive institutions are well established (Scott 2001, p. 51). The cultural-cognitive element focuses on "the extent to which behavior is informed and constrained by the ways in which knowledge is constructed and codified" (Scott 2001, p. 68).

Since the R&D programs and collaborative arrangements examined in this paper are user-oriented and often explicitly aiming at commercialization and industrial application, it is relevant to ask who chooses to engage in these projects and what characterizes the interaction that takes place. In other words, the study combines an examination of the institutional elements triggering collaboration between organizations, with analysis of the institutional carriers and mechanisms of interaction.

Other empirical studies have analyzed institutionalization processes in biotechnology focusing on origins, acceptance and spread of entrepreneurship at the university department (Colyvas and Powell 2007). In the case of industrial research institutes the entrepreneurial practices and focus on innovation activity (that would benefit the industry sector) were explicitly formulated upon creation of the institutes. Interestingly, the collaborative projects of these institutes also include university-based researchers and doctoral students. That brings attention to re-shaping of traditional division of roles. One interesting example of this

traditional divide can be seen in an examination commissioned by the Swedish government of the Swedish professors' privilege that ensures that university-based researchers are entitled to innovations unless they write any other agreement (Governmental Bill 1998, p. 154). There it was argued, with reference to a commissioned examination of the privilege in 1996, that even if the privilege was abolished, there would be no real change "since the employer has right to the employee's inventions only if the use of them falls within the employer's area of activity". These processes involving academic inventors also enforce the argument of embeddedness of economic action in social structures and relational ties (Granovetter 1985, p. 504). In the current study, these structures and ties boil down to analysis of collaborative firm-university-institute R&D programs and interactions between organizations.

The analysis of organizational development, interorganizational relations and institutional agreements also benefit from previous studies of the sources of institutionalized practices and norms. The three categories of sources of institutionalization (Zucker 1987) include both sources external to the organization, i.e. the institutional environment as an aggregate and other individual organizations, and internal sources, i.e. organization structure.

The first category focuses on external sources of institutionalization and includes studies of the institutional environment described in some cases as programs and procedures which function as highly rationalized myths (Meyer and Rowan 1977). The surrounding environment can also be described as an organizational field being those organizations that constitute a recognized area of institutional life, defined in terms of increased density of interaction, information flows, and membership identification, as outlined in DiMaggio and Powell (1983).

The second category is also external to the organization, and focuses more on inter-organizational ties and less on organizational ecology approaches and role of the state. The third category instead focuses on internal organizational structure as a source for generating institutional elements. This third category brings attention to within-group processes that can also affect and internally induce change, as in the case of the study of museums as an organizational field (DiMaggio 1991). The intriguing conclusion of that study with regards to institutionalization and legitimization processes, shows contradictory dynamics where the success and expansion of an organizational form also lead to including professions (devoted to education of the public) that "offered *de*legitimating criticism" suggesting that

institutionalization also can bear openings for substantial change (DiMaggio 1991, p. 287). This is considered relevant also in the analysis of the industrial research institutes' R&D activities in emerging fields of technology. Since emerging technologies have the potential of changing existing industries, this also implies that, by incorporating R&D activity in an emerging technology, the links to existing industry can be weakened. Thereby also potentially contesting legitimacy and existing 'institute identity' linked to that industry that in hindsight was a strong force that lead to the creation of the industrial research institute.

To conclude the section reviewing previous organizational studies and institutional theory, three points are put forward below with implications for institutes' integration of new skills. Firstly, that the shift towards collaborative innovation processes has also brought about new organizational forms and modes of interaction and consequently also agreements and contracts between actors to manage collaborative innovation activities. These collaborative efforts regulated by formal agreements and strategy documents are one way to integrate new knowledge. Secondly, that previous studies stress organizational inertia consisting of routines and existing norms and exploitation strategies are hampering processes aiming at transforming organizations to explore new fields of knowledge and technological opportunities. Thirdly, that the cognitive processes of defining novel emerging areas of technology and innovation are also targeting processes integrating knowledge and capabilities of end-users and interdisciplinary science fields.

Nevertheless, collaborative efforts also have geographical settings with implications for knowledge production and integration of new skills. Spatial proximity has been shown to be conducive to the spread of new scientific findings (Feldman 2000) and commercialization of science-based innovations as well as capitalization of commercial ventures (Feldman 1999; Zucker and Darby 1996; Gertler and Levitte 2005). The focus on the geography of collaboration is also present in international comparative work (Archibugi and Coco 2004; Lukkonen et al. 1992) and in studies on regional collaboration (Owen-Smith and Powell 2004). Activities based on a high degree of non-codifiable knowledge, such as most research and development, are thought of being especially benefitted by geographical proximity (von Hippel 1994; Maskell and Malmberg 1999; Malmberg and Maskell 2006). However, besides spatial closeness, institutional, organizational and relational dimensions of proximity are also put forward as crucial for effective exchange of knowledge (Gertler 2003; Amin and Cohendet 1999, 2000, 2005). As previously stated, this paper acknowledges the importance of

institutions internal to the organization, also in shaping the character of links between actors in innovation networks. Examples of such links involving firms, university and research institutes show that collaborative efforts that benefit from geographic proximity span from sharing laboratory facilities and equipment to joint researcher capabilities (Eriksson and Ericsson 2005, pp. 44-45).

3. Results from the case studies

In this section the development of the research institute sector in Sweden is briefly presented, the concepts of applied research and semi-public industrial research institutes are discussed and different types of institutes are outlined. Thereafter follows a more detailed presentation of the two institutes studied in the paper. Finally, results from the case studies are reported.

3.1 History and organization of the Swedish industrial research institutes

It has been proposed that the particular concept of research institutes has evolved from the idea that basic exploratory research can be combined with research guided by purposes of usefulness, as pioneered by for example Louis Pasteur (Stokes 1997; Mazzoleni 2005). This idea can be traced back to philosopher Francis Bacon that developed the notion of cooperative research for the advancement of society (Bacon 1627; Sargent 1996). Today, these ideas are carried forward in various types of organizations where collective research is performed. Here we concentrate on semi-public research institutes, which are supported by both industry and governmental funding and are specialized in particular science and technology fields or with a special industry sector focus.

The formation of an industrial research institute sector in Sweden started during the 1920s, in part inspired by earlier European examples, e.g. institutes in Germany and the UK. The first Swedish research institute was created following a private initiative from steel-producing firms; this institute was active in the field of metallography. In the 1940s, during World War II, came the first public initiative to start several new institutes while reorganizing the Institute of Metallography into a semi-public institute (Sörlin 2006). The newly formed institutes were dedicated towards applied research in strategically important fields where

Swedish firms were active, i.e. forest products, food and textiles respectively. These institutes were given considerable support from public funds already from the start.

During the 1950-60s several new institutes were created and governmental funding of their activities grew rapidly. The institute sector became larger and more diversified during this time. But from the early 1980s and onwards, research policy shifted to prioritize universities as research performers with diminishing relative funding of institute-based research as a result. The end of the Cold War and deregulation of several important markets further exacerbated this development (Sörlin 2006). Also during the late 1990s public support for the institutes diminished substantially.

Considerable restructuring, reconfiguring and reorganizing efforts have been predominant in the Swedish institute sector during the last ten years, with the main aim of more effective allocation and use of resources. This course of development has also been observed in many other European countries where institutes have been under pressure to reassess their activities and change in accordance with the needs of actors in the innovation systems while using their resources more efficiently (Preissl 2006). Most Swedish institutes have previously been run as foundations, which limited their actions and financial freedom. Therefore, a lot of the institutes have been transformed into limited companies with partially private and partially public ownership. At the same time, the public ownership of the Swedish institutes has been organized into a holding company, IRECO, which more recently changed its name to Research Institutes of Sweden Holding AB (IRECO 2007; RISE 2009).

In 2007 there were twenty one public and semi-public industrial research institutes in Sweden in total, most of them had their roots in older institutes, while a few had been created during the 1990s (Ministry of Enterprise, Energy and Communications 2007). As mentioned before, the three categories of industrial research institutes found in Sweden (Sörlin 2006) include institutes dedicated towards particular scientific fields and targeting technical solutions (such as surface chemistry or computer science). Institutes belonging in the second category focus on specific industry sectors considered to be particularly important for Sweden and with a long tradition in the country, such as the example of forestry and paper processing technology. The third category consists of institutes that specialize in particular service

functions including for example in technical evaluation and testing. The cases, described in the following section, are examples of the first and second category, although there are elements of testing and evaluation also in their activities.

3.2 Industrial focus - the institute for paper and pulp technology

Paper technology and forestry have a long tradition in Sweden, as is for example shown in policy document from 1940s outlining key issues in a "future program for industry" (Svennilson and Walderström 1942, p. 20). The Swedish Pulp and Paper Research Institute (STFI – svenska träforskningsinstitutet) was created in 1944 and restructured in 1968 also incorporating laboratory facilities (Centrallaboratorierna). Alongside research in chemical processes in papermaking, the institute also specialized in sensor technology applied to process control systems utilizing engineering physics skills and core competence to develop industry solutions[1].

The current STFI-Packforsk was formed through the merger of several other institutes in order to better cater to the needs of Swedish pulp and paper industry, and dubbed the 'super institute' (STFI 2002). The process of merging STFI with Packforsk (Swedish packaging research institute) was initiated in 2001 (STFI 2001) and was followed by also incorporating relevant parts of Framkom (IRECO 2002, 2003, 2004). These organizational changes also enabled a move towards activities and development higher up in the value chain, going from paper and pulp process technology, to also incorporating media, packaging as well as research and development in other packaging materials than paper.

The institute STFI-Packforsk is organized in three divisions of competence: 1) Fiber, pulp, energy and chemicals; 2) Process and product innovation; 3) Packaging, media and materials (STFI-Packforsk 2009). About one third of the institute is owned by the government via IRECO (now RISE), the remaining part is owned by private interest organizations and companies (Ministry of Enterprise, Energy and Communications 2007, p. 30). The institute's cluster research program is based on participating companies' sharing investments (and risks)

[1] Inteview with Lennart Eriksson, former Vice President STFI-Packforsk, 2nd October 2008.

in a research program developed in a dialogue between institute and industry (STFI-Packforsk 2007). The aim is to "create a research programme that is on the cutting-edge of and focusing on the future needs of our (STFI's) customers" (STFI-Packforsk 2008a, p. 4). EU funding and internationally focused research strategies and programs are also gaining importance for the institute (FTP 2005). Other important research programs include the Sectoral research program (Branschforskningsprogram) that receives substantial governmental support and is carried out in collaboration between the institute, industry and academia together with sector organizations in forestry and wood industry.

In year 2007 STFI-Packforsk had 267 employees making it one of the largest industrial research institutes in Sweden (STFI-Packforsk 2007). About a third of the institute's employees have completed postgraduate education. The institute has a strong core competence in areas of chemistry (fiber, pulp and energy), papermaking and packaging, also including materials and media (STFI-Packforsk 2007, p. 20). This is also reflected in collaborations in process technology and chemistry with university affiliated professors and sharing lab facilities with KTH (Eriksson and Ericsson 2005. p. 45). Historically, even education and skills in physics were important for core competence in sensor technology (Marklund 1994, p. 112).

The user-oriented innovation activities of product development at the institute involve interdisciplinary approaches, thus involving staff with still other educational backgrounds. One example of this is the Human-product interaction laboratory (HPI) where customers of the institute are provided with added knowledge as to how their packaging solutions and printed materials are perceived by end-users (STFI 2007, p. 14). This includes utilizing competence of psychologists to reveal perception of new packaging solutions and products also incorporating knowledge from the interface of psychophysics and cognitive psychology (Lindberg and Fahlcrantz 2005). Another example, also reflecting incorporation of preferences of end-users, is the development of new materials where other competences, for example in design, are part of the R&D team.[2]

For STFI-Packforsk it is noteworthy that although much of the core competence is based on chemistry of paper and pulp technology, historically the integration of skills in physics was of

[2] Inteview with Lennart Eriksson, former Vice President, STFI-Packforsk, 2nd October 2008.

importance for the institute's entrepreneurial activity in sensor technology. This technology was used, but not developed, by industry itself so the institute's entrepreneurial activity in this area was expanded[3]. More recently, the interdisciplinary technology field of visual interfaces is described as a "new field of expertise at STFI-Packforsk" (STFI-Packforsk 2005, p. 2) following a co-operative agreement with the industrial research institute Acreo, further described in the following section of the paper.

3.3 Specialization in scientific fields - institute for research in electronics, optics and communication technology

The second case study institute is the industrial research institute Acreo AB active in the fields of optics, communication technology and electronics. In 2007 Acreo had 140 employees and was engaged in a multitude of collaborative research and development projects in areas such as imaging sensors, high speed transmission of data, printed electronics, silicon carbide electronic devices and broadband- and TV-distribution (Acreo 2007). The institute also runs several advanced lab facilities and offers possibilities for small-scale production as means of evaluating the market potential for new products and components. Approximately a third of Acreo's employees hold a postgraduate degree. The most common disciplines among employees with postgraduate education are engineering physics and computer technology.[4]

Acreo was created in 1999 through the fusion of two other research institutes, Institute of Optical Research (IOF) and Industrial Microelectronics Center (IMC). IMC was in turn created in 1993 through the restructuring of the Institute for Microwave Technology that had been in operation since 1968 (Olsson et al. 2002). IMC performed industrial research dedicated towards microelectronics, initially being heavily dependent on R&D projects for military applications. IOF had been active in the field of optics since 1955 and the early research focus concerned for example evaluation of image quality of military lenses and cameras. Acreo's predecessor IMC was experiencing the pressure of diminishing military orders and governmental support during the 1990s, in stark contrast to the situation in the 1980s when Cold War prompted plentiful support for this type of research. The institute thus

[3] Inteview with Lennart Eriksson, former Vice President, STFI-Packforsk, 2nd October 2008.
[4] Interview with Mårten Armgarth, Manager Sales, Acreo, 14th October 2008.

had to seek new customers in the private sector in order to maintain its level of funding. In comparison with other Swedish research institutes, IMC, which later became a part of Acreo, developed a strong commercial focus fairly early on. This also means that competences in for example knowledge management, commercialization of research and patenting have been built up in this particular institute for more than a decade. This has resulted in the creation of several spin-off firms, some of them based on patented technology. These competences are also used and transferred by way of services for small- and medium sized innovative firms in the field of technology and business development.

3.4 Organizational development at STFI-Packforsk and Acreo

The Swedish institute sector has seen dramatic changes during the last decade. As we mentioned earlier, many institutes have been reorganized into limited companies. Also, public financing of research activities has been gradually switching from guaranteed basic grants to project funding awarded in competitive research calls. These changes have brought with them an increasing need for formalization of institutional agreements and development of new organizational forms at the institutes. To face external pressures and adapt to new roles in the Swedish R&D system the two case study institutes have experienced considerable organizational change during the last decade. Two different developmental paths have been chosen by these institutes, these will be elaborated on in this section of the paper. Recent changes in the organization of STFI-Packforsk and Acreo are summarized in Figure 1.

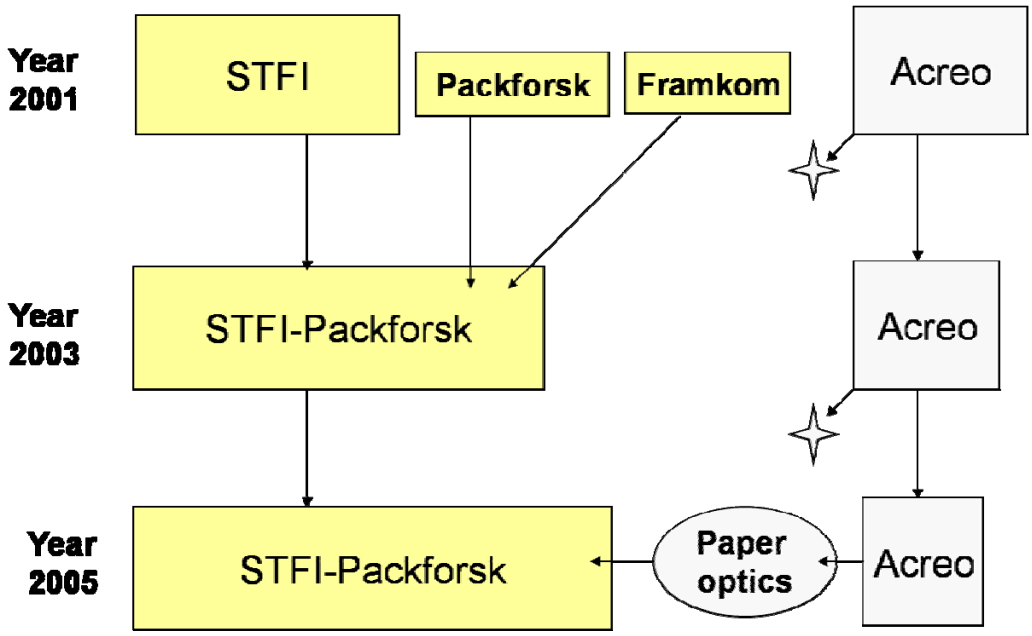

Figure 1. Timeline of recent reorganizations at the case study institutes.[5]

The strategy of the first institute studied in the paper, STFI-Packforsk, has been one of mergers and integration of several research institutes into one organization which spans across forest-based value chains including: energy and chemicals from renewable resources, printing and media as well as packaging materials and packaging logistics.

The most poignant example of integration of research units is the merger between STFI and Packforsk which was announced during 2001, and completed in 2003. These two institutes had limited collaboration before the merger in 2003, but an opportunity for integrating complementary knowledge bases, working interdisciplinary and increasing competitiveness trough competence along the whole value-chain from raw material to consumer was recognized. Moreover, globalisation within the industry was also identified as a driver for the merger (STFI 2001). Packforsk had a different type of customer base than STFI and was geared more towards consulting and further education rather than research and development. Packforsk was also materials neutral, which means that they worked with plastic and metal packaging materials, as well as paper. Packforsk being considerably smaller than STFI had some apprehensions about losing its identity in the merger, and with it also customers. The

[5] Acreo spin-offs are illustrated as shooting stars.

potential synergies that were expected were clearly emphasized in the process of the merger, as shown in statement from the CEO of Packforsk (STFI 2002, p. 4):

"We have been nodes in each other's networks for a long time. […] After we started working on the integration last year, we mutually discovered new aspects that will result in a more systematic survey. […] All the employees will now hopefully build up their own networks within the company."

An important symbolic choice has also been to start referring to the institute as a 'research company' instead of 'collective research institute' (STFI 2002, p. 6). In the following years more mergers and acquisitions followed, even during 2004 which was called a year of "no new radical changes" at STFI-Packforsk (STFI-Packforsk 2004). This is contrasted with Acreo where there have not been any major mergers for this institute since it was created by combining two separate institutes in 1999. Instead it has been focusing on refining its core activities and creating spinoff firms where business opportunities have arisen (Acreo 2007). Nevertheless, the ownership structure of Acreo has changed somewhat and thus also its immediate organizational surroundings. During 2005 a group of firms called Swedish ICT Research was formed, it includes Acreo and four other institutes active mainly in computer science and IT. There are currently no official plans for any mergers between Acreo and the other institutes in the group.

An interesting intersection between STFI-Packforsk and Acreo was formalized in 2005 and can be seen in Figure 1. That year marked the start of a formal collaboration between these two institutes[6] backed by a transition of a research group in paper optics from Acreo to STFI-Packforsk. This collaboration and its implications are further discussed in the section that follows.

3.5 Organizing for interdisciplinary collaborative research

The aspect of collaboration on interdisciplinary research applications is analyzed here through a study of a research group in paper optics which resided at Acreo up to the year 2005 and

[6] Previous collaboration had been carried out by participating in the same research programme as in the case of the Print research programme (T2F – tryckteknisk forskning) funded by the Knowledge foundation (KK-stiftelsen).

then transferred to STFI-Packforsk (Acreo 2005). This small research group consisting of physicists began working on projects concerning optic properties of paper in 1995, as part of activities in the field of surface characterization. The area of paper optics grew in importance for the research group and STFI-Packforsk was recognized as a better organizational match than Acreo[7]. Already before the actual transfer in 2005, the paper optics group collaborated with STFI-Packforsk, for example commissioning user-oriented scientific tests in the perception laboratory. The transfer was seen as a possibility to better be able to handle new challenges within areas such as light scattering modelling and perception. At STFI-Packforsk, on the other hand, research was carried out analysing light scattering properties of the paper surface, see for example Hansson and Johansson (2000). While at Acreo the group was a part of the division for 'Visual Interfaces' together with other researchers focusing on optic properties of displays. At STFI-Packforsk the paper optics group has been integrated into the division for 'Appearance and Imaging' where they work closely with researchers in ergonomics and psychology. At the same time researchers from the group are also collaborating with researchers in chemistry, mechanical engineering and designers employed at other divisions of STFI-Packforsk and external to the organization.

It can then be argued that the transfer to STFI-Packforsk provided an interdisciplinary organizational setting for the paper optics research group with the pulp and paper industry as a common denominator. Even though the research group had previously been involved in collaborations with employees from STFI-Packforsk, it was more of an arm's length relationship rather than substantial integration. According to interviewed researchers, the transfer has offered new possibilities for taking their R&D activities in new directions, for example into the field described as 'psychophysics' examining users' perceptions of new materials and visual appearance of paper and printing. For example the 'whiteness' of paper is one area studied at STFI-Packforsk in order to determine how paper is perceived by different user groups and for different product groups.

However, organizing for interdisciplinary research also comes at a certain cost. At Acreo the paper optics group had greater opportunities for scientific and professional *intradisciplinary* progress and exchange, together with other physicists working in for example optics and

[7] Interview with Mårten Armgarth, Manager Sales, Acreo, 14th October 2008.

photonics. If the group had stayed at Acreo they could possibly have been continuing to evolve their research into other applications within the field of optics, not just paper. At STFI-Packforsk the group takes part in an *interdisciplinary* progress and exchange, contributing with their disciplinary backgrounds which are more unique in that setting. Their skills are applied on a limited set of product categories though which opens up some avenues for R&D but perhaps closes others.

To conclude, Figure 1 illustrates mergers, spin-offs and transfer of organizational units from one institute to another as in the example of paper optics which constitutes a merge of physics-based competence in optics combined with institute core competence in paper and packaging material characteristics. With reference to studies of institutionalization processes as a trigger for change (DiMaggio 1991) the incorporation of new competence trough organizational change and re-organization towards 'materials neutral' and interdisciplinary approaches to product development (merge with Packforsk, interdisciplinary HPI-laboratory and visual interfaces example) brings attention to renewal processes in traditional industry sectors such as forestry and wood processing. Framed in terms of institutionalization of practices of interdisciplinary research teams, these renewal processes at institutes and within industry can be seen as a process where "institutionalization bears, if not the seeds of its own destruction, at least openings for substantial change" (DiMaggio 1991, p. 287). This raises questions about how successful organizational expansion in new knowledge domains also influences industrial and institute identity and the organization of areas of R&D activity. This is further discussed in the concluding section of the paper.

3.6 Formalization of new norms in R&D programs

The logic of governmental funding of institute research has been altered in a substantial way during recent years. The 'no strings attached' base funding has diminished considerably, and to some extent been replaced by project-based funding that is sought for in competitive calls. In these new types of calls industrial partners are expected to pitch in and contribute to the funding, often both with workforce and cash. Collaborative projects which span across industry sectors and involve several levels of the value chain are considered to have considerable innovative potential and are therefore encouraged by funding agencies. Industrial research institutes are expected to take the role of "powerhouses in innovative networks" and

coordinate activities of business actors, academia and own researchers (IRECO 2004). This development in the direction and organization of public funding is exemplified here by two publicly initiated R&D programs. Firstly, we will analyze the sectoral research program (BFP program) that has been created exclusively for the pulp and paper industry and thus affects STFI-Packforsk. Secondly, the Institute Excellence Center program from which Acreo receives a portion of its funding.

The BFP program stretches over six years and gives researchers possibilities to seek funding for projects of four different types. These are collaborative R&D projects, prototype building, explorative high-risk R&D and contact stimulating projects (with the aim of building and strengthening international consortia). Industry co-funding is required for all projects, but collaboration between institutes and academia is not a prerequisite for receiving funding[8]. In this type of research program project applications are evaluated on the basis of their relevance, quality, probability of being realized, usefulness and strategy for knowledge dissemination.

The Institute Excellence Centers research program differs from BFP in that it supports a few chosen R&D centers that distribute funds received from government and business partners to various projects themselves. The aim of the program goes beyond supporting projects though. In that sense the cluster programmes developed at STFI-Packforsk are more comparable with regards to long-term program development in a dialogue between institute and industry. The overarching goal of Institute Excellence Centres is to create arenas for internationally competitive specialized research which also serve as meeting places for different actors interested in this research. Institute Excellence Centers are also seen as a way of building new brands in R&D (e.g. Acreo Fiber Optic Center) and attracting additional research contracts and funding from other sources. Close collaboration with both industrial and academic partners is required in the program. R&D projects supported by the centers are supposed to contribute to innovations in individual firms and creation of new firms. Education of PhDs is a compulsory part of excellence centers' activities. The applications for this program were

[8] The STFI-Packforsk's Cluster research program has another type of collaborative arrangements between institute and companies. The Cluster program "comprises of a number of project clusters that have been developed from consideration of what is scientifically and technically promising, matched against the industrial needs and interest expressed in discussions with partners…" where partner customers are described as "a customer that has signed a three year or longer agreement to finance the Cluster research programme at STFI-Packforsk at a minimum level based on the company's annual turnover" (STFI-Packforsk 2008b, p. 1)

assessed on aspects such as innovativeness, quality and competence of actors, but also long term strategies for sustaining the center and commercializing research results.

A model agreement for chosen Institute Excellence Centers was proposed by the funding agency in this program, regulating aspects such as disclosure of research results. This was seen as crucial in order to fulfil the aims of the program with respect to creation of industrial innovations and new firms. An important aspect of the institutes' role in excellence centers is that they can serve as a neutral owner of intellectual property rights (IPRs) and guarantee fair access to them for all involved parties, for example through free licenses. The IPRs being owned by research institutes also minimizes the risk of them being sold abroad which is seen as positive by the public funding agencies.

The institutes recognize importance of collaboration with university in joint R&D and for recruiting personnel. On the other hand, difficulties are also recognized when formulating agreements for collaborative research projects with academia. This is to some extent caused by conflicting goals and different external evaluation criteria applied to academia and institutes. While the institutes are interested in protecting both their own and their industrial partners' intellectual property rights and trade secrets, academic researchers are interested in publishing their results as quickly as possible. This means that institutes have a double interest when it comes to scientific publications. On one hand, institutes want to ensure review of publications before they are submitted and before filing for patent of potentially industrially useful and valuable results. At the same time, academia and research technology organizations such as institutes also have an interest in publishing novel and interesting results without any delay whatsoever in order not to loose cutting-edge scientific excellence. Nonetheless, when the benefits of collaboration are recognized by and apparent to all involved actors, agreements do get formed and delays acceptable to all parties are negotiated and contracted. There are also examples of co-invented patents and co-authored papers between involved parties.

The analysis of research programs affecting the institutes' organization and strategy showed that programs aimed at the two studied institutes differed considerably on various points. This reflects differences in type of institute as well as in previous development. STFI-Packforsk

stands for both continuity and renewal targeted by a sectoral research program and cluster programs developed in a dialogue with both individual firms and sector organizations (STFI-Packforsk 2007). About one third of R&D activities are devoted to explorative research of future strategic importance (with governmental funding and EU-funds). Also internationalization of customer base as well as research funding and strategy is increasingly important also for the forestry sector (FTP 2005). In addition to this, exploration of new materials with integration of skills in packaging, food safety, and designer skills also stands for renewal processes of more traditional pulp and paper R&D activity. Meanwhile Acreo has received funding for setting up two excellence centers which focus on narrow R&D fields. This type of centre is a result of joint institute-firm-university application for funds in competition with applications made by actors in other technology areas. They target both internationally competitive environments for research, development and innovation, and the creation of attractive meeting places for institutes, companies of all sizes and university (Vinnova 2005).

4. Concluding discussion

The organization of interdisciplinary and collaborative R&D efforts at semi-public industrial research institutes has been analyzed in the paper through a case study of two institutes. In the following section the results are summarized and further studies are discussed.

4.1 Comparison of the case studies

The different types of institutes represented by the cases here show that institutes with an industry sector-oriented focus also go through processes approaching the market by integrating end-users and suppliers in their innovation processes and projects. On the other hand, the institutes described as technology focused are streamlining their areas of activity resulting in changes in organization of R&D activities also including defining new categories of skills and competence central to the organization. Table 1 outlines the character of organizational change, strategy, collaborative R&D programs and funding logic of research programs of the two institutes studied in the paper.

Table 1. Organizational change, strategy and funding logic of research programs of the two institutes Acreo and STFI-Packforsk.

	Acreo (electronics, optics and communication technology)	**STFI-Packforsk** (paper, pulp, printing and packaging technology)
Organizational change and strategy	Streamlining the organization, selling divisions, creating spinoffs, focus on generic technology applied in several industries	Mergers and acquisitions, integrating along value chain, absorbing new capabilities, sector focus, service and R&D function to industry
Collaborative R&D and funding logic	Institute Excellence Centers program aiming for internationally competitive specialized research centers, competitive calls for funding open to consortia of institute-industry-university	Sectoral research program (BFP) and Cluster program, International forest-based technology platform, project based funding, industry co-funding of cluster programs and individual projects

The results of the paper convey a story of organizational change in the rise of new technological opportunities. The institutes studied in this paper are examples of two different processes of change and adaptation in R&D intensive organizations. The initial focus of Acreo on scientific fields based on generic technology has lead to refinement and specialization in the selected fields with ties to several sectors but not being dominated by a specific industry sector's interests. On the other hand, the initial focus on a particular industry as in the case of STFI-Packforsk has lead to broader, interdisciplinary scope of R&D activity with clear considerations of sector relevance. Hence the integration of new skills and complementary competences is influenced by previous phases of interaction and existing relational ties, such as buyer-supplier relations, but also entails exploration of new science and technology applications and skills to identify new niches for technology and new materials with potential future customers.

4.2 Conclusions and further studies

The results of the cases studied here respond to the main question asked in the paper by identifying three ways of integrating diverse skills and involving a broader set of actors in development of emerging fields of technology. These are: organization of collaborative research in formalized industry-specific R&D programs, purposeful organizational change also including a redefinition of categories of core research competence and finally by targeting 'open' innovation processes characterized by incorporation of both end-users and

skills of neighboring technology areas. In the cases studied, the incorporation of new skills by targeting open innovation processes involving end-users, designers and psychologists is also further strengthening the interdisciplinary scope of R&D activity.

The review of previous organizational studies provides an analytical framework for the empirical studies in terms of regulative, normative and cultural-cognitive institutions surrounding the institutes' innovation activities. This is illustrated by formal agreements between organizations in search for novel applications of technology (regulative), organizational inertia by existing routines hampering or practices facilitating exploration of new fields (normative), but also the importance of cognitive processes of defining categories describing new areas of R&D activity central to the organization (cognitive). We argue that the studied institutes are interesting examples of how organizations cope with integrating new skills for several reasons. Firstly, they are involved in collaborative projects at the core of innovation processes of interdisciplinary technology. Secondly, the rules of conduct of collaborative R&D are also formalized in institutional agreements showing how the realms of public and private science co-exist (in some cases in separate divisions) within the same institute. Examples of this are conditions for scientific publication and more entrepreneurial activities and agreements regulating intellectual property developed in collaborative projects. The user-oriented approach of innovation carried out at the institutes is far from the linear conception of innovation and also leads to incorporating disciplines examining users' perception of new products and materials to take advantage of emerging markets for new niches and applications of technology.

This development also provides some interesting points of departure for further work on institute identity and core competences relating to industry identity. Firstly, with reference to studies of institutionalization processes as a trigger for change (DiMaggio 1991) the case of paper technology versus introducing a 'materials neutral' technology focus at STFI-Packforsk brings attention to renewal processes in traditional industry sectors. Thereby it would be particularly interesting to further analyze how successful organizational expansion in new areas of R&D activity also influences industry and institute identity. This could improve understanding of organizational and cognitive processes of redefining fields (or categories) of research activity that are considered being areas of core competence.

A second avenue of further research includes a closer examination of the structure of collaborative networks and changes over time by analysis of co-authored papers between university, institute and industry in addition to processes of co-invented patents. Thereby, processes of internationalization of R&D could be captured and analysis of citation patterns can also reveal cross-disciplinary interaction over time.

Thirdly, it is also warranted to examine inertia to change, both internally at R&D-intensive organizations and externally, in settings with both public funding and with substantial industrial investments. Hence, further studies of funding regimes can contribute to a better understanding of organizational inertia as well as of openings for substantial change stemming from potentially disruptive interdisciplinary emerging fields of technology.

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